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SPECIAL SECTION ON EXPERIMENTAL TELETERMINALS
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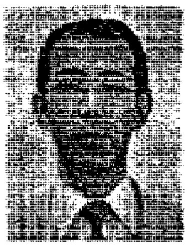

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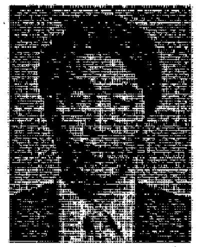

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INDAX: An Operational Interactive Cabletext System

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Abstract—**INDAX is a local area home information system de- ;loped by Cox Cable Communications, Inc. for the delivery of video- x services to residential customers. The large bandwidth provided / this medium allows integration of one-way (teletext) with two-way ideotext) transmissions into a cohesive delivery vehicle. As a data :livery mechanism, INDAX is well suited to many different types of rvies. Among the earliest service offerings are generalized informa- ›n retrieval and transaction services such as home banking and opping. Implementation and traffic characteristics of these services 'e described in the following sections. In addition, INDAX supports teractive entertainment options such as opinion polling in conjunc- ›n with the standard entertainment programming. Status monitor- g and control services such as security monitoring and energy anagement can also be delivered via INDAX. While the traffic model scribed is oriented towards a residential service, the modular sys- m architecture readily supports differing traffic statistics by the ldition of communications and processing modules.**

INTRODUCTION

NDAX, or interactive data exchange, is a two-way interactive cabletext system. The system, designed and im- :mented by Cox Cable Communications, Inc., is currently erating in San Diego, CA and Omaha, NE as one of the ındard residential cable services offered. This article de- ibes the service and presents the design and implemen- ion philosophy subscribed to in the development of this ›duct.

The first step in introducing a new communication sys- n is the evaluation of existing technologies. Much effort had been expended in the videotext field to provide home banking, home shopping, news, opinion polling, and general time sharing services. These services were found to be lacking in several areas including the number of simultaneous users supported, the cost of service, lack of adaptability, and the sophistication required of the consumer. Perhaps the most serious shortcoming, however, was the lack of an integrated system providing all of these services.

Cabletext provides a communications medium which successfully addresses these problem areas. It supports one-way data broadcasting, or teletext allowing cost effective information retrieval by tens of thousands of simultaneous users. At the same time, two-way data transmission supports transactional services such as home banking and shopping. Of no minor concern to cable system operators is the ability to modify specific subscriber authorization without a service call. This is important both as a marketing tool and to prevent theft of services. All of these features were included in the early design of INDAX, but the key for long-term market survival went beyond these readily identifiable services. The internal goals which overshadowed these specific services were that the system have high availability/reliability, be flexible, and be highly modular. Active participants in the developing videotext marketplace are the first to admit that consumer demands are largely unknown.

INDAX, then, is a delivery medium and service system providing the consumer access to a wide range of data and transactional services. These services, local, national, and international in scope, are delivered via state-of-the-art technology to a technically naive audience. The range of services delivered by IN-

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DAX includes the ability to pay bills, transfer funds from one bank account to another, obtain information on consumer products, order and pay for these products direct for delivery to the subscriber's home, play games, take educational courses for credit with live tests automatically recorded and graded, and order airline and theater tickets. Several illustrative examples of these services follow.

Example 1: Mrs. Jones, an INDAX subscriber, decides she wishes to pay certain bills electronically via INDAX including local power, home mortgage, city utility, and various credit card companies. She provides this list to the INDAX banking service provider along with the necessary account information. When a bill to a creditor on this list comes due, she enters the INDAX banking service and is prompted with the list of creditors. For each bill to be paid, she indicates the amount and the date payment is to be made. This information is taken by the banking service system and relayed to the creditor's bank. Fig. 1 is a typical screen from a bill paying session.

```
HOMSERV                                  B00326

+--------------------------------------------+
|            BILL PAYMENT REVIEW             |
+--------------------------------------------+

STARTING BALANCE              $    725.00
TOTAL CURRENT PYMTS           $    125.00
TOTAL FUTURE PYMTS            $      0.00

1.  VISA                 100.00    010182
2.  ELECTRIC COMPANY      25.00    021482


+--------------------------------------------+
| TO CANCEL, KEY IN ITEM NO.                 |
+--------------------------------------------+
| KEY 0 TO COMPLETE PAYMENTS             +   |
+--------------------------------------------+
|PRESS ENTER TO PAY MORE BILLS               |
+--------------------------------------------+
```

Fig. 1. A typical screen layout from an INDAX paying session.

Example 2: Other INDAX services are not explicitly invoked by the subscriber. Due to the very large number of subscribers supported by INDAX, the system employs a distributed architecture. As many decisions as possible are pushed to the lowest possible level. In particular, the decision as to whether or not a subscriber can view a particular program is made in the converter. This requires ability to download to the converter the subscriber's personality describing which services are authorized. The personality contains information as to which services have been purchased, what parental access restrictions the subscriber wants to restrict their children's viewing, a personal identification number to authorize pay-per-view services or to override the parental access restriction, and the option of allowing emergency alert messages to turn on the TV and tune to a designated channel to receive warnings of hazardous weather or other important messages. This service is also employed by the operations staff to manipulate converter personalities to reduce theft of services.

INDAX DESIGN GOALS

Three characteristics were identified as key to the long-term success of INDAX: availability/reliability, flexibility, and modularity.

In order for INDAX to be successful in the consumer marketplace, the consumer must think of it as a dependable friend. We refer to this as the "utility" theory of operation—service available upon demand. While INDAX brings together several different state-of-the-art technologies with their inherent uncertainties, these must be hidden from the consumer. Thus, INDAX provides for error detection and correction, automatic equipment reconfiguration, and on-line maintenance. The goal is to provide a service with no perceptible errors.

Although many studies have been conducted around the various videotext and teletext systems undergoing trial, there is currently no blueprint for operating such a system as a business. Consumer demand for information products is uncertain; information services are coming and going almost daily. Even display technology is evolving rapidly. To successfully cope with this environment, INDAX must retain flexibility to support a diversity of services provided by many different service providers.

Finally, in order to be economically viable as an operational system, INDAX must be available in a wide range of capacities with a graceful growth path. This requirement is best met by a modular system in which each module provides full functionality with modules added as consumer demand increases.

SYSTEM ARCHITECTURE

The extended system architecture of INDAX is illustrated in Fig. 2 and comprises service provider's systems, the INDAX headend and database, an interface into the cable plan, a conventional two-way active CATV plant, and, finally, the consumers' converters. The INDAX converter is referred to as a home terminal unit (HTU) because of its enhanced capabilities.

The service providers represent a key decision made early in the development of INDAX: it is neither desirable nor possible to provide all data and transactional services from a single, centralized system. Thus, service providers are a key part of the total system. There are two basic types of service providers: information providers and transaction servers. The information providers provide data such as national news, sports, weather, and other syndicated items in the INDAX database. These items are updated automatically as required by the nature of the data.

Typical information providers include The Source Telecomputing Corporation for national and international news, and Copley Newspapers in San Diego for local news.

The transaction server is best characterized by the need for an interaction between the service provider and the subscriber. Typical transaction services include home banking provided by HomServ, Inc. and home shopping provided by ViewMart, Inc. In order to provide a consistent appearance to the consumer, it was necessary to develop standards for screen layout. These standards provide a uniform layout for common information such as routing instructions and error messages.

The computer system selected for the headend was Tandem T/16. This system was chosen primarily because of its redundant NonStop architecture. This architecture addressed the

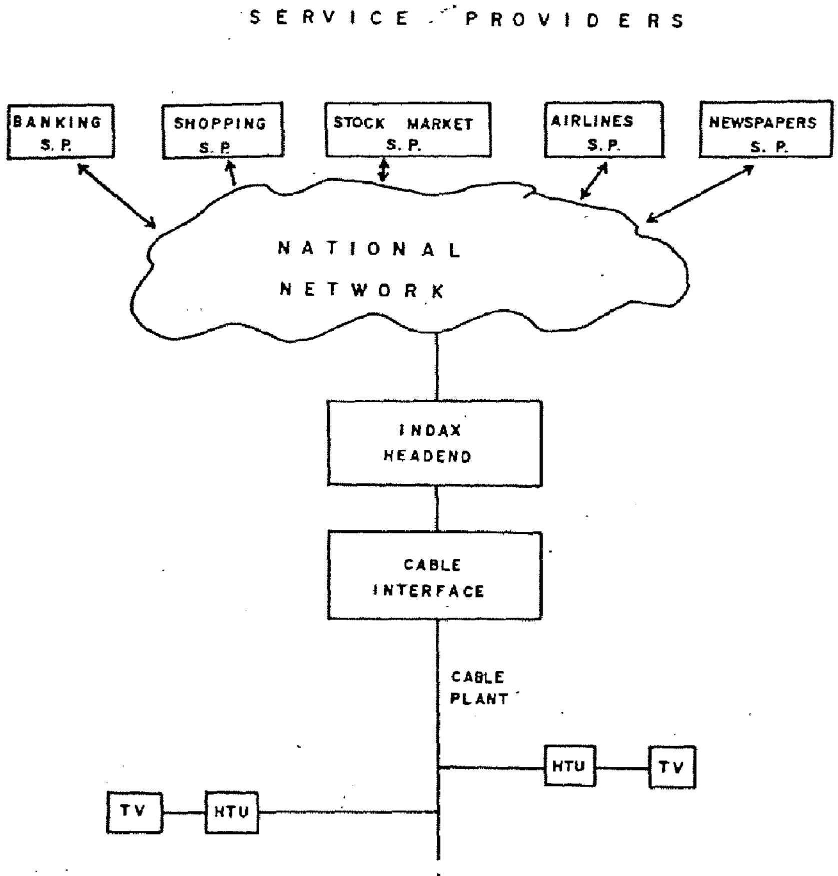

Fig. 2. Typical INDAX system architecture.

ree design principles of reliability/availability, flexibility, id modularity. The Tandem's basic architecture provides for dundancy of all critical components including processors, ripherals, and power supplies, as well as redundant comunication paths connecting these components.

Disk drives are operated in a mirrored or fully duplicated ode. In this mode, data written to one drive of the mirrored ir are automatically written to its associated drive. Data can read from either drive with the file manager optimizing seek ne. Performance degradation on write operations is minor cause the operations are overlapped. An actual performance iprovement is possible on read operations because of the erlapping and seek optimization. Since INDAX is heavily ased towards reads, mirrored files enhance performance.

Fig. 3 illustrates the INDAX communications structure in ore detail. The communication control units (CCU's) provide e communications interface between the headend computer stem and the cable plant. They are microprocessor conolled with an ROM bootstrap and a control program downaded from the Tandem T/16. The redundancy possessed by Tandem is carried to these units as well. Each CCU has two rts: a primary and backup. The CCU automatically switches the event of a communications failure. INDAX supports up 120 CCU's in a single system. Each CCU may be employed her as a one-way database transmitter or as a two-way comunications concentrator. Details are given in the following section. The RF modem associated with a CCU is treated as an integral part during failure detection and reconfiguration. Thus, a failure in either the CCU or the RF model causes selection and reconfiguration to a new CCU/RF modem pair.

Interconnection between the Tandem and the CCU's uses the synchronous data link control (SDLC) multidrop protocol. The physical level is RS232C running at 28 kbaud. While the CCU'S are normally adjacent to the Tandem T/16 with a direct connection, the link may be operated remotely over communications lines at any data rate. This connection is established through a master clock/protocol conversion board which provides synchronous clocking and conversion of the RS232C to RS422 electrical interface, allowing for physical level multidropping. The RF cable link between the CCU's and the HTU's uses a modified form of CSMA/CD running at a 28 kbaud rate.

CABLE PLANT CHARACTERISTICS

The typical subsplit CATV plant provides for two frequency ranges: 50–400 MHz from the headend outward (downstream) and 5–30 MHz towards the headend (upstream). In the downstream direction, INDAX is able to use frequencies generally abandoned because of conflict with FAA transmission since data signals can be transmitted at a lower power level than video signals. Therefore, INDAX downstream data use this 108–132 MHz spectrum. In the upstream direction,

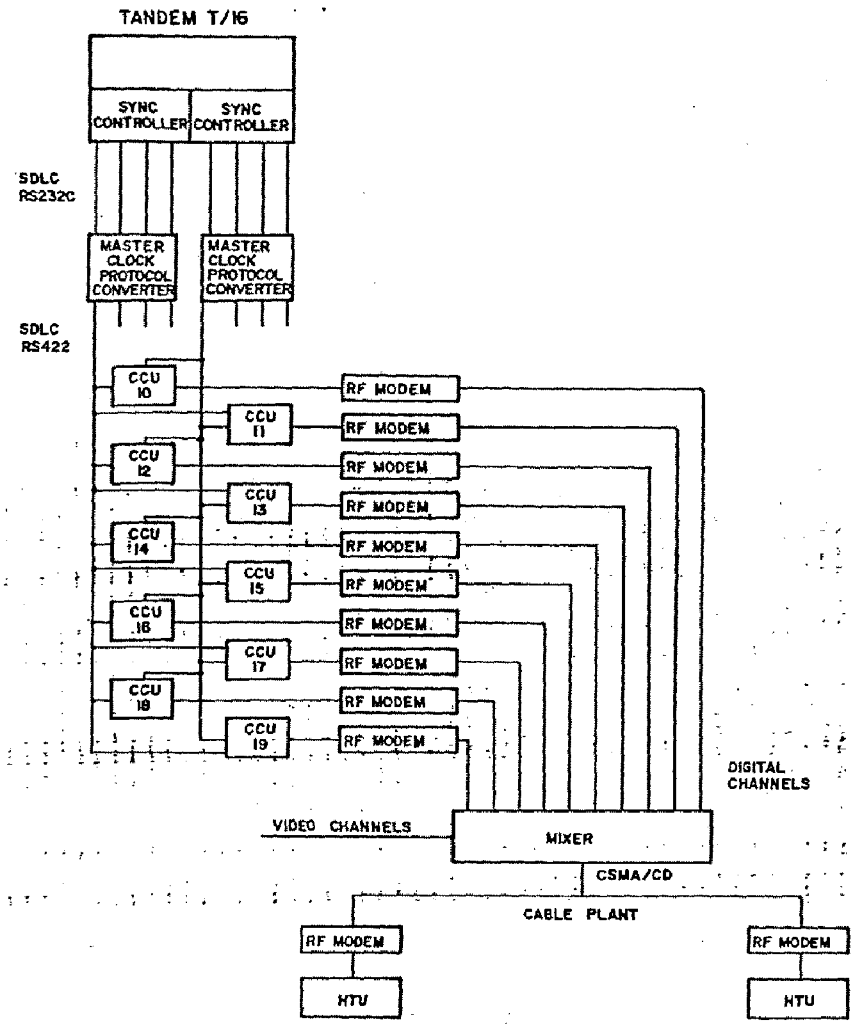

Fig. 3. INDAX digital/RF communications architecture.

ingress of external radiation sources was considered and upstream transmissions were placed in the 17-29 MHz frequency spectrum.

The bit error rate (BER) of data is directly related to the modulation technique used and to the carrier-to-noise ratio (C/N) at the receiver input. In the CATV environment, the FCC requires that the video signal measured across a 4 MHz bandwidth shall not be less than 38 dB C/N. Each INDAX data channel occupies a 300 KHz bandwidth, giving a 13 dB C/N improvement over the 4 MHz video C/N. Experiments indicate a 10^8 bit error rate (BER) with a C/N of 20 dB. In order to meet FAA signal requirements, INDAX signals are carried 16-20 dB below normal video signal levels, leaving more than 10 dB headroom. The upstream C/N ratio is much more difficult to project because of the tree configuration. A noise funneling effect occurs from all branches of the tree and combines back towards the headend. The upstream signals must therefore be carried at a level approximately equal to that of the return video level. Field measurements indicate that the C/N of an upstream plant with 200 miles of active cable is approximately 45 dB.

Due to the fact that ingress into the system on any one of the distribution legs funnels into the system, it has become necessary to allow for isolation of each leg from the rest of the plant. This is accomplished through the use of a technique called bridger switching. All distribution legs branch off of the main trunk through a bridger amplifier. These amplifiers contain an RF switch in the upstream (5-30 MHz) signal path under remote control from the headend site. In the event of severe ingress, the branches of the tree are isolated until the problem area has been identified. Frequency agility of the data modems is used in conjunction with the multiplicity of data channels to dynamically reassign communications to noise-free channels.

SUBSCRIBER COMMUNICATIONS REQUIREMENTS

The basic objective of the INDAX system can be simply stated: to provide information retrieval and transaction processing services to the cable TV subscriber in an economically feasible manner. Two specific assumptions relative to this objective impact the selection of a communication protocol. First, a typical INDAX system has tens of thousands of subscriber terminals connected to the headend system. Second, the communication load generated by each subscriber is very bursty with each interaction having a relatively low duty

ycle, i.e., there is a high ratio of peak bandwidth to average andwidth.

Given the cable communication medium, the focus on com- unication design considerations changes considerably. The edium provides a large bandwidth to support expected sys- m traffic while the coaxial cable implementation ensures at the communication channels are very stable with low ror rates. Thus, the communications medium provides high ailability with a small incremental load due to error retries. is large available bandwidth and high availability, however, rmits the attachment of the large number of subscribers to e cable system. The timing, stability, performance, and odularity aspects, coupled with the lack of actual statistics ncerning the traffic profiles for such a system indicated a ed for very careful protocol selection and system engineer- g.

The modular design of INDAX requires a typical trans- tion to traverse several communication paths during proc- ing, as shown in Fig. 3. The physical topology of the cable m is the conventional CATV tree structure emanating from headend through trunks, amplifiers, splitters, and drops. wever, logically the topology can be considered as one cable ich passes every terminal analogous to a broadcast medium. DAX supports a total of 120 28 kbaud data channels: 40 stream and 80 downstream. In order to allow bidirectional nmunications, the 40 upstream data channels are mated to lower 40 downstream data channels to form 40 bidirec- nal, 28 kbaud, full duplex channels. The remaining 40 vnstream data channels may be used only for one-way in- mation (teletext). The CCU's, in turn, communicate with the idem T/16 which serves as a central message switch to ap- ation processes. These processes may reside in the same t processor or in a service provider's host processor, in ch case the INDAX system performs the gateway function, necting the subscriber to the service provider. In addition he message routing, the CCU's and the Tandem T/16 per- n the required protocol conversion before passing the sage to the next entity.

To eliminate the need for developing and implementing a lly new protocol, existing communication protocols were yzed in relationship to the INDAX system requirements. se protocols which best addressed the requirements were yzed further for eventual implementation in the system. carrier sense multiple access with collision detection MA/CD) protocol was selected as a basis for the communi- ons between the HTU and the CCU's. This selection was d on the stability and performance characteristics of the ocol in support of a large number of user terminals pre- ing bursty traffic. SDLC was selected as the communica- protocol between the concentrators and the host proc- . The requirements indicated a relatively small number of entrators, multidrop capability, and a more uniform traf- low. X.25 was selected to support the gateway connection een the host processor and the service providers. Cur- y there is a mixture of implementations, using both a pub- acket switching network and dedicated connection sys-

here are two basic types of data services offered by IN- DAX: direct information retrieval and transaction processing. The control function is a third application required of the IN- DAX system and must also be supported by the data services.

Information Retrieval

The information retrieval process provides the subscriber with the ability to retrieve a page of information such as news, weather, advertising, or financial data. This type of informa- tion consists primarily of textual data with some limited graphic content. Because of the characteristics of the medium, the necessity to display text on a TV screen, the text must be edited tightly to maximize the information conveyed to the subscriber. The graphics content is based upon mosaic or line drawings with limited resolution. The data organization must be kept simple and easy to use because of the general con- sumer appeal of such a service. This goal is also consistent with the distributed control since the access algorithm is imbedded in the HTU. The information retrieval process deals with rela- tively static data and therefore utilizes one-way transmission as its primary delivery vehicle.

In the one-way mode the pages of information are contin- uously cycled on the communication channel by the CCU. To access a frame, an HTU tunes to the correct channel, examines the stream of information on that channel, and, upon detect- ing the correct identifier for the frame being requested, grabs the information from the channel and displays it to the sub- scriber. Thus, the response time for access to a frame of one- way data is random, dependent on the position of the frame in the cycle when the HTU device begins searching.

The access structure provided by INDAX is a tree structure with intermediate nodes called menus and leaves called data pages. There is always a root menu frame from which access to all of the other frames in the database is accomplished. This root frame has a unique identifier which consists of the chan- nel on which it is located. This root frame is always presented to the subscriber as his entry point into the INDAX system.

Each menu frame may have one or more choices from which the user can select. The frame which related to a partic- ular choice on the menu has an identifier which is stored with the menu frame being viewed by the user. To access the par- ticular frame which the terminal user has selected from the menu, the terminal unit would retune to the appropriate chan- nel and examine the frames cycling by until the one desired is detected, captured, and displayed. If subsequently directed to display another frame of information, the terminal simply repeats the process and retunes to the appropriate channel and captures the required frame.

The teletext delivery mode requires a larger bandwidth but has the advantage of requiring no host processor interaction. It does, however, require intelligence in the HTU with a corre- sponding limit on the flexibility and complexity of the data- base. Conventionally, videotext systems have used the switched telephone network as a delivery medium while tele- text systems have predominantly used the vertical blanking in- terval (VBI) of a broadcast video signal. The cable TV network provides a communications medium with the unique ability to combine one-way (teletext) and two-way (videotext) delivery in an integrated system.

ombination of tiers and a parental access level. This constiites the channel personality. The HTU provides for subscriber election of channel or information source and, upon such election, compares the subscriber personality to the se-cted channel personality. If the channel is assigned to one of ie tiers the subscriber has purchased and satisfies the parental ccess level, then viewing is authorized. Otherwise, service is enied to the subscriber. This function requires local memory the HTU and maintenance of a global database at the headid. This information is downloaded from the global data-ise upon the occurrence of any change. Additional special ents may be identified as impulse pay-per-view. For these ents, special subscriber action is required to authorize ewing and the subscriber is consequently billed per event ewed.

To implement this distributed control, messages are interianged between the headend and the HTU. Upon power up, e HTU transmits a message to the headend indicating that it on line. In response to this message, or any time the subriber's personality changes, the headend transmits a copy of e subscriber personality to the HTU for local storage. Similly, all channel personality information is transmitted to the TU upon power up or any change of the personality datase. Pay-per-view events require the transmission of a message om the HTU to the headend upon successful authorization the viewing of a pay-per-view event by the customer.

INDAX TRAFFIC MODEL

Although home information systems are currently very ich under discussion, actual traffic information for such a stem is essentially nonexistent. There has been no previous plementation in a single system of the services provided by DAX. Therefore, subscriber usage patterns had to be estiated by drawing analogies from information available on mparable type systems. As the subscriber base grows and ore traffic data become available, the model is altered to rect reality.

Based on the INDAX information service design, the oney interactive service must support a capability of 5000-000 pages of information. Based on an average page size of 0 bytes and a 10 s average/20 s maximum response time, s requires 25-50 one-way channels. Due to the broadcast ture of the one-way service, the only parameters influencing engineering of these channels is the desired database size, rage page size, and required response time.

Based on the analogs and early traffic statistics for two-way eractive services, the model shown in Fig. 4 resulted. Inded in this model are estimates of average information and nmand packets which will be interchanged between the minal and the host processor. The rationale for these asnptions is the residential nature of INDAX. Therefore, it is umed that all transactions will occur between 6:00 P.M. and 00 P.M., Monday through Friday. This compression is used account for peak loads; in fact, there will be system usage ing other periods, but the system is engineered to handle a ir-hour peak each day. Traffic measures indicate that peakis not this severe. For purposes of engineering, the average sion is assumed to be comparable to paying these bills. In

SUBSCRIBER ASSUMPTIONS

80 hours/month (4 hours/day * 5 days/week * 4 weeks/month)
18 sessions/month/subscriber
70-900 seconds/session
7-17 transactions/session
2 packets/transaction - 1 upstream, downstream

TRAFFIC ASSUMPTIONS

120 bits/average upstream packet
1610 bits/average downstream packet

RESULTANT AVERAGE TRAFFIC VALUES

.00087-.002 packets/second/subscriber
.76-1.8 bits/second/subscriber
.056-.0094 active sessions/subscriber

Fig. 4. INDAX projected subscriber traffic model.

Model Assumptions for Metropolitan Area

Average City Size = 125,000 homes passed
Cable Subscribers = 75,000 subscribers (60% of homes passed)
INDAX Subscribers = 30,000 subscribers (40% of cable subscribers)

Resultant Traffic Values

1687 simultaneous sessions
26 packets/second
22800 bits/second
3 data channels at 30% efficiency - CSMA/CD 28k baud

Fig. 5. Communications demands in a typical metropolitan area.

reality, some are more complex (catalog shopping), some far simpler (a pay-per-view message). These individual subscriber estimates were combined with estimates of total subscriber population in a typical metropolitan area. The percentage of this total population which will subscribe to INDAX services was estimated and extrapolated to give the aggregate traffic requirements shown in Fig. 5. These figures indicate a requirement for relatively few two-way communication channels to support the expected traffic in the typical system.

The headend computer capacity is engineered on the basis of the number of packets per second per subscriber (0.0087-0.002) and a model which characterizes the power of a single T/16 processor in terms of the number of transactions per second it can support. Additionally, the number of active sessions per subscriber per month is used to determine the number of simultaneous users which the system must support.

This is a simplistic model of system performance but experience indicates that it is adequate for gross system tuning. More precise tuning is being carried out as the body of subscriber usage data expands.

Traffic peaks occur for certain types of applications and must be supported by the system in a graceful manner. One such application is impulse pay-per-view wherein the subscriber can authorize the viewing of an event for a charge at the time of viewing. Special events, such as world title boxing, cause heavy peak traffic loads immediately prior to the event. A similar application is opinion polling wherein viewers are asked to indicate their opinion during a video program. This is a service pioneered by Warner-Amex with their QUBE system in Columbus, OH. Cable News Network currently carries such questions as part of their public affairs programming. Responses are sent to a host processor for tabulation. In both cases, the load is externally generated and cannot be controlled by the headend computer system.

Other uncontrolled high load generators exist and include HTU restarts wherein messages are transmitted from every

TABLE II
INDAX DESIGN OBJECTIVES, REQUIREMENTS, AND CHARACTERISTICS

SYSTEM CHARACTERISTICS:
A very large population of terminals.
Bursty traffic from the terminals.
Low duty cycle per access.
Short messages.
Potential large traffic peaks.
Coaxial Cable Operation -- RF, 28K baud, 225μs propagation delay 10^{-8} bit error rate.
Unknown operating statistics.
SYSTEM OBJECTIVES/REQUIREMENTS
High system reliability/availability.
High system stability.
High system responsiveness to the user -- less than 2 seconds total communications delay on 99% of all transactions.
No perceptible errors to the user.
Service Level -- 2-second internal INDAX response time for 99% of all two-way transactions.

HTU affected by a major power outage. In each case the selected protocol must be stable in its response to peak loads.

Two other types of services present differing load characteristics. Applications typified by home security and energy management require a monitoring transaction to be sent by the HTU on a constant cycle. While fundamental change is required in the delivery mechanisms, this represents a constant bias load with communication and processor power required for support. Periodic personality updates and security checks represent large traffic volumes but are controllable and are scheduled for off-peak periods.

In any case, due to the evolutionary nature of INDAX, the design must readily accommodate the additional traffic generated by new applications. This requires the ability to easily add processor and communications capacity. In heavy overload conditions, control and stability is achieved by the CCU invoking load control to force the HTU's quiescence until the system has again reached equilibrium.

The design objectives, requirements and characteristics of INDAX are summarized in Table II.

The protocols selected must be able to achieve the design objectives and support the system characteristics. Each communication link in the INDAX system was examined and existing protocols were analyzed for use on the particular link. The HTU-to-CCU protocol and CCU-to-host processor protocol are discussed below.

Two candidate protocols were evaluated for the HTU-to-CCU communications: polling and contention. While polling protocols have been the norm in the cable industry, they do not adequately address the requirements of the INDAX system. In particular, polling protocols are not well suited to situations involving many infrequently communicating terminals. In order to maintain responsiveness with a polling protocol in this environment, channel utilization would be unacceptably low.

The discussion below assumes that the reader is familiar with the various contention schemes in use today (see, e.g., [3]). The contention protocols such as ALOHA and CSMA/CD, are, however, designed to support these types of characteristics. The performance characteristics of a protocol are a critical factor for consideration when making a protocol selection. It is very important to examine and understand the throughput behavior of the protocol for different offered traffic loads in the system. Of equal importance is the ability of the protocol to obtain adequate throughput over a wide range of offered traffic loads, and the stability of the protocol throughout this range. The physical communications channel has a physical capacity limit which is determined from the physical operating characteristics of the hardware employed. The maximum achievable throughput for an access mode determines the true capacity of the channel.

CSMA/CD offers good throughput and stability under heavy loads and provides for a robust error check via a data loopback requirement.

The maximum achievable capacity for the pure ALOHA protocol approaches $1/2e$ or about 18 percent. The slotted ALOHA protocol increased the capacity of the system $1/e$ or about 37 percent. The achievable capacity of the CSMA/CD protocol can be over 90 percent depending on the specific physical system parameters involved. The capacity is sensitive to and varies depending on the propagation delay of the channel.

For INDAX analysis we approximate the true load via Poisson arrivals from an infinite population, negligible collision detection time as compared to the burst propagation time and treat retransmissions as independent Poisson arrivals. In addition, the packets are assumed to be of constant length. The worst case propagation delay for INDAX is 1.95 ms and normalized to the average packet transmission time is 31 ms which gives $a = 0.06$. These characteristics yield a capacity for the INDAX implementation of approximately 60 percent.

Fig. 6 gives the performance curve derived for INDAX showing the offered traffic versus the expected throughput.

As suggested by the literature, the offered traffic (G) and throughput (S) have been normalized to the packet transmission time. The delay characteristics derived for INDAX are shown in Fig. 7.

The communication environment between a CCU and the Tandem T/16 is significantly different. Because of the concentration performed by the CCU, there are few CCU's handling two-way traffic, each with a relatively regular load. These characteristics fit a polling protocol very well. In addition, the CCU's providing one-way information transmission require no interaction with the Tandem T/16 except for periodic status checks and database downloading. This allows for effective use of a multidropped architecture. SDLC was selected because of extensive hardware and software support available.

SUMMARY

INDAX has been developed to provide interactive information retrieval and transaction services delivered via a CATV network. The principle issues addressed in this development included the choice of the residential marketplace, a determination of the grade of service to be provided, product standard

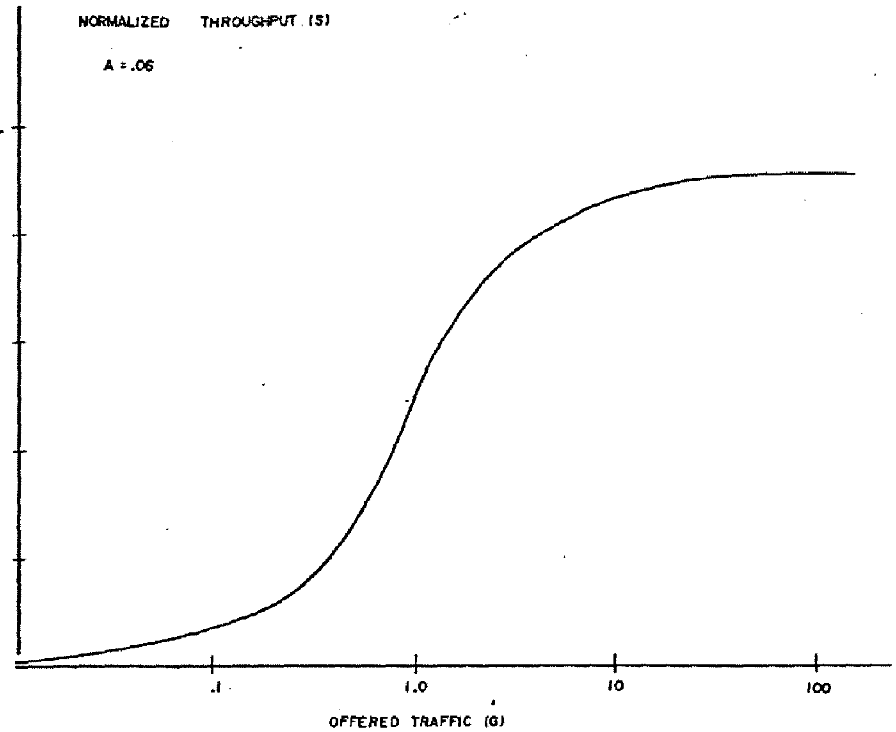

Fig. 6. Relationship between offered traffic and normalized throughput for CSMA/CD including retransmissions.

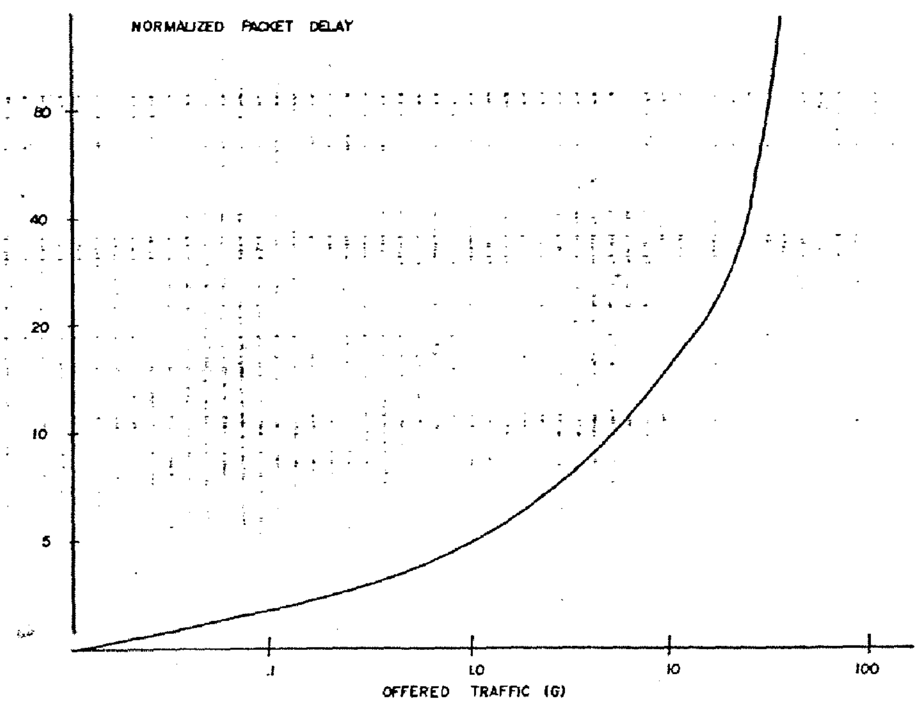

Fig. 7. Relationship between offered traffic and packet delay.

ensure a consumer-friendly system, and communications otocol selection. INDAX is operational in two CATV systems today and will expand into several others within the next ar. This will allow the determination of accurate customer age patterns for the first time in a commercial home information system.

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[3] A. S. Tanenbaum, *Computer Networks*. Englewood Cliffs, NJ: Prentice-Hall, 1981.

[4] L. Kleinrock, *Queueing Systems, Volume I: Theory.* New York: Wiley, 1976.

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M. L. Ellis received degrees in electronics from the U.S. Air Force Electronics College, Colorado Springs, CO, and San Diego College of Engineering, San Diego, CA.

He is currently Director of Advanced Technology for Cox Cable Communications, Inc., Atlanta, GA. He is responsible for new hardware technology development as well as being the coinventor of the Cox INDAX system. Prior to joining Cox, he was Executive Vice President and Director of Engineering for ICC, Inc., where he was responsible for the development of the first interactive fire security and energy management system developed for CATV use ever to receive a UL Grade AA listing.

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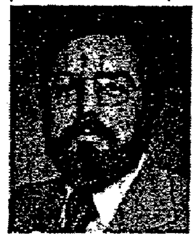
G. W. Gates (S'66–M'73) received the Ph.D. degree in electrical engineering and computer science from Michigan State University, East Lansing, where he concentrated on the design and analysis of computer systems.

He is currently Director of Research and Development for Cox Cable Communications, Inc., Atlanta, GA. In this capacity, he is responsible for all aspects of communication systems development for the CATV multiple system operator. Prior to joining Cox, he spent several years at Bell Laboratories in the development of operating systems for highly reliable computer systems and control systems for voice messaging systems.



J. M. Smith (A'81) received degrees in busines from Piedmont College, Demorest, GA.

He is currently Director of Software Tech nology for Cox Cable Communications, Inc., At lanta, GA. In this capacity, he is responsible fo all software development for Research and De velopment for the CATV multiple system opera tor. Prior to joining Cox, he was involved wit Loral Electronic Systems in their development o ESM avionics for the U.S. and NATO militar forces. Before that, he was employed by The Southern Company in their Technical Engineering Services group whicl provided a wide variety of technical services for the utility's operating companies.

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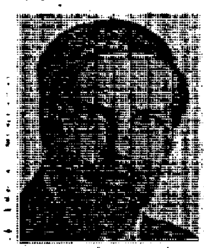

G. L. Peckham graduated from the U.S. Militar Academy, West Point, NY, and has completed advanced degrees in computer science specializing in databases and software systems.

He is currently Manager of INDAX Operation and Quality Assurance for Cox Cable Communications, Inc., Atlanta, GA. He is responsible fo the technical operational support of field INDAX systems and the testing of the INDAX system.

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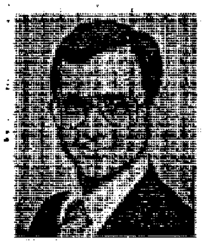

H. P. Gray (M'82) received degrees in industrial engineering and computer science from the Georgia Institute of Technology, Atlanta, where he concentrated on the design and analysis of information systems.

He is currently Staff Consultant, Research and Development, for Cox Cable Communications, Inc., Atlanta. He is responsible for the systems architecture and protocol design of the various communications systems utilized within Cox. Prior to joining Cox, he was employed for several years by The Southern Company, where he managed the development of data processing systems in the nuclear, fossil fuel, and plant maintenance areas.